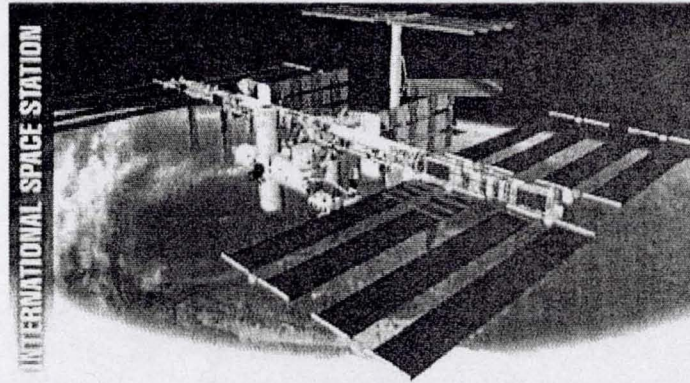




Source of Acquisition
NASA Johnson Space Center



International Space Station External Contamination Status [4096-101]

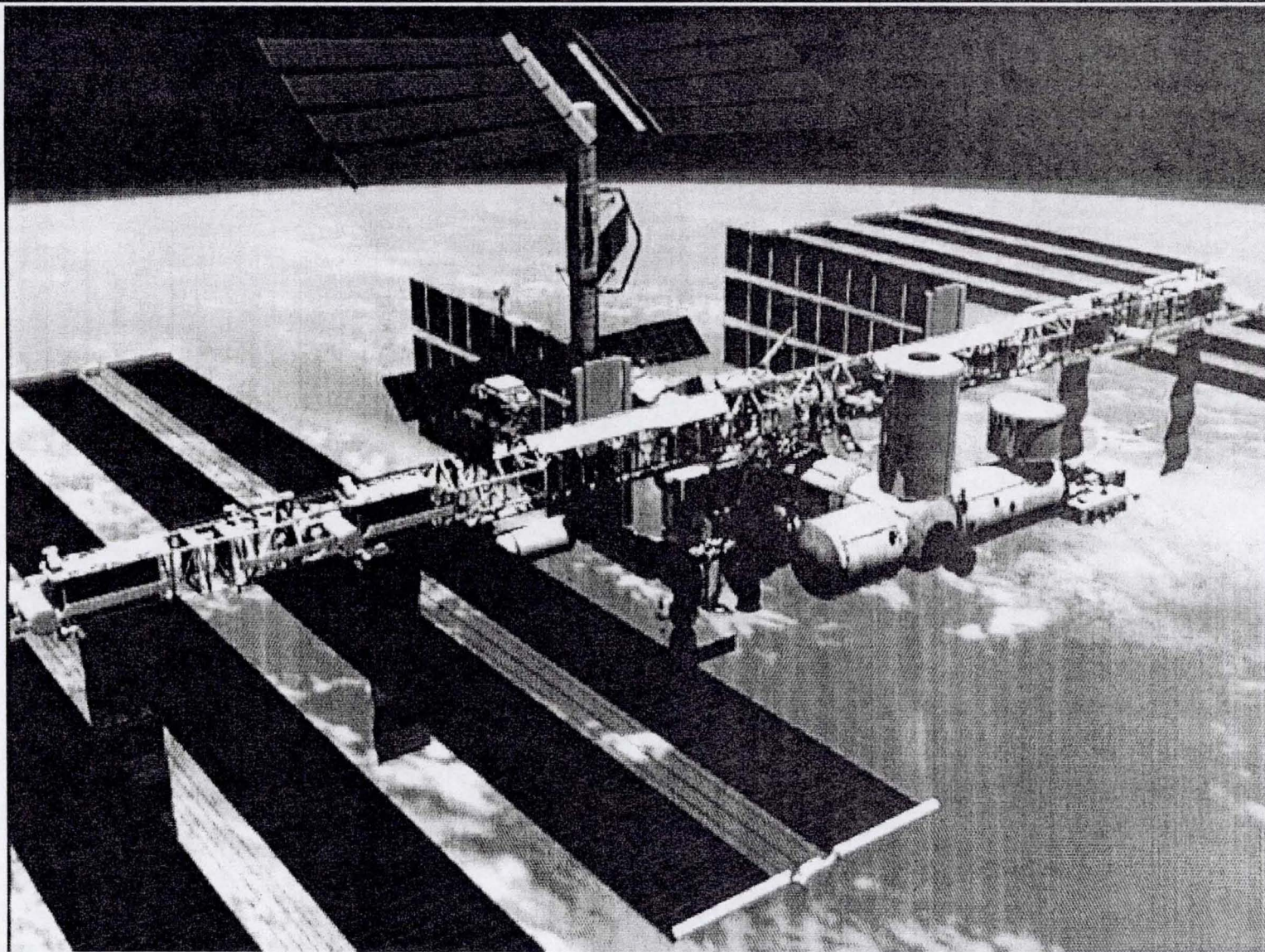
**Presented at the Conference on
Optical Systems Contamination and Degradation II:
Effects, Measurements, and Control**

**SPIE's 45th Annual Meeting
San Diego, California
August 3, 2000**

**Ron Mikatarian
Carlos Soares**



International Space Station



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Ronald.Mikatarian@sw.boeing.com

Page 2

June 2000



External Contamination Requirements



Requirements

● Contaminant Releases:

- ➡ At the ISS system level, molecular deposition onto ISS sensitive surfaces, from all contamination sources, is limited to 130 Å/year.
- ➡ For active vacuum vents, the design and operation shall meet the requirement that the molecular column density shall be less than 10^{+14} molecules/cm² when viewed from selected ISS locations.



External Contamination Requirements



Requirements (continued)

- **Contaminant Releases (at the ISS system level):**

- Total molecular deposition: 130 Å/year
- Quiescent molecular deposition: 30 Å/year
 - Materials outgassing
 - Venting
 - Leakage
- Non-quiescent molecular deposition: 100 Å/year
 - Proximity Operations
 - Mated Operations
 - Reboost and Attitude Control

- **Molecular Column Density:**

- Quiescent periods: 10^{+14} molecules/cm² (along line-of-sight)
- No requirement during non-quiescent periods



External Contamination Requirements



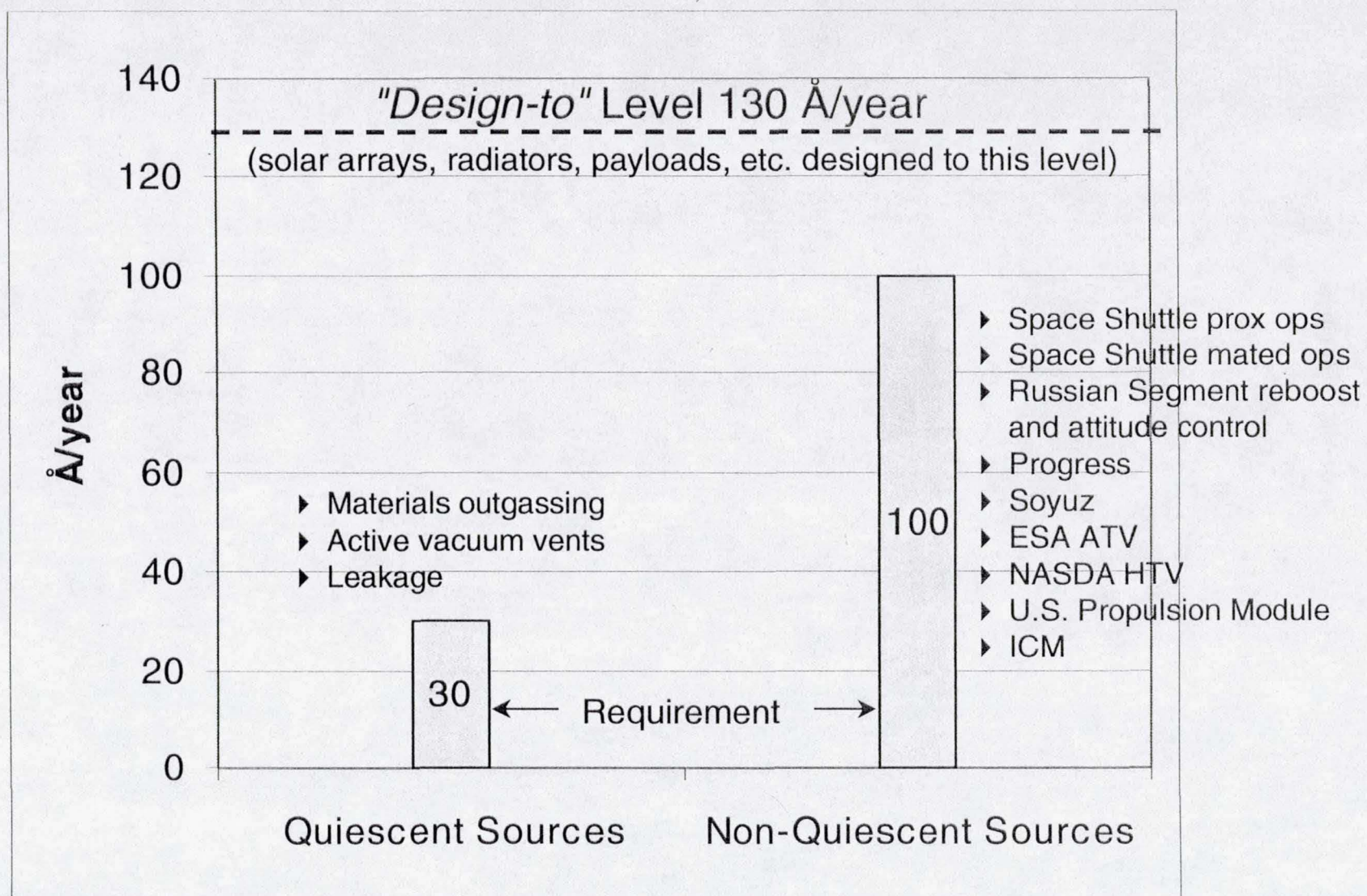
Requirements (concluded)

- ***“Design-To” Requirement:***

- ➡ All vehicle hardware suppliers and all users must design to the external contamination environment stated in the previous chart; e.g.,
 - ➡ Solar arrays
 - ➡ Radiators (active and passive)
 - ➡ Sensors
 - ➡ Payloads (“design-to” requirement not imposed on Attached Payloads)



External Contamination Requirements





ISS External Contamination Sources



- **Materials outgassing (vacuum exposed materials)**
- **Vacuum venting**
- **Leakage**
- **Propellant purging**
- **ISS reboost and attitude control:**
 - **Russian thrusters on Service Module and SPP**
 - **ESA Automated Transfer Vehicle (ATV) as part of the Russian Segment**
 - **U.S. Propulsion Module**
 - **U.S. Interim Control Module (ICM)**
- **Proximity operations:**
 - **Space Shuttle**
 - **ESA ATV**
 - **NASDA H-2 Transfer Vehicle (HTV)**
 - **Russian Progress**
 - **Russian Soyuz**
- **Space Shuttle mated operations:**
 - **Fuel cell and waste water dumping**
- **Attached and pressurized payloads**



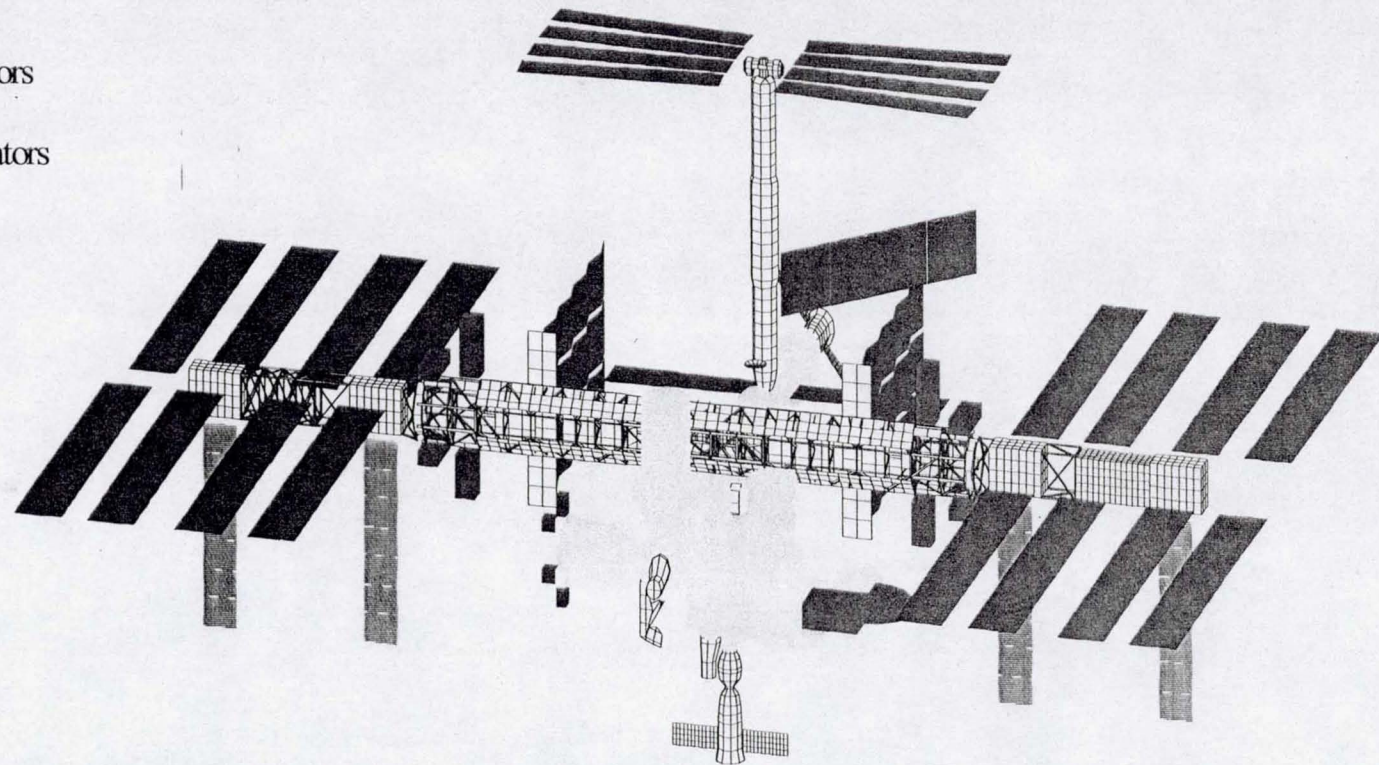
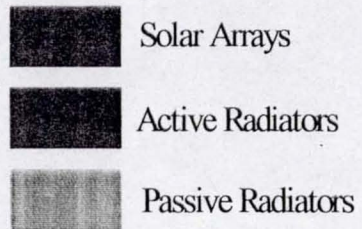
ISS External Contamination Sensitive Surfaces



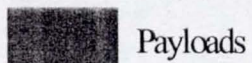
- Debris shields
- Solar arrays
- Radiators (active and passive)
- Viewing ports/windows
- Vehicle optical sensors, cameras, etc.
- Transmitters
- Payload locations:
 - S3 Truss
 - JEM EF and ELM
 - Columbus external payload facility
 - Service Module and SPP
 - Lab window



ISS External Contamination Sensitive Surfaces



Windows



Pressurized Modules



ISS External Contamination Control



Pre-Launch Verification

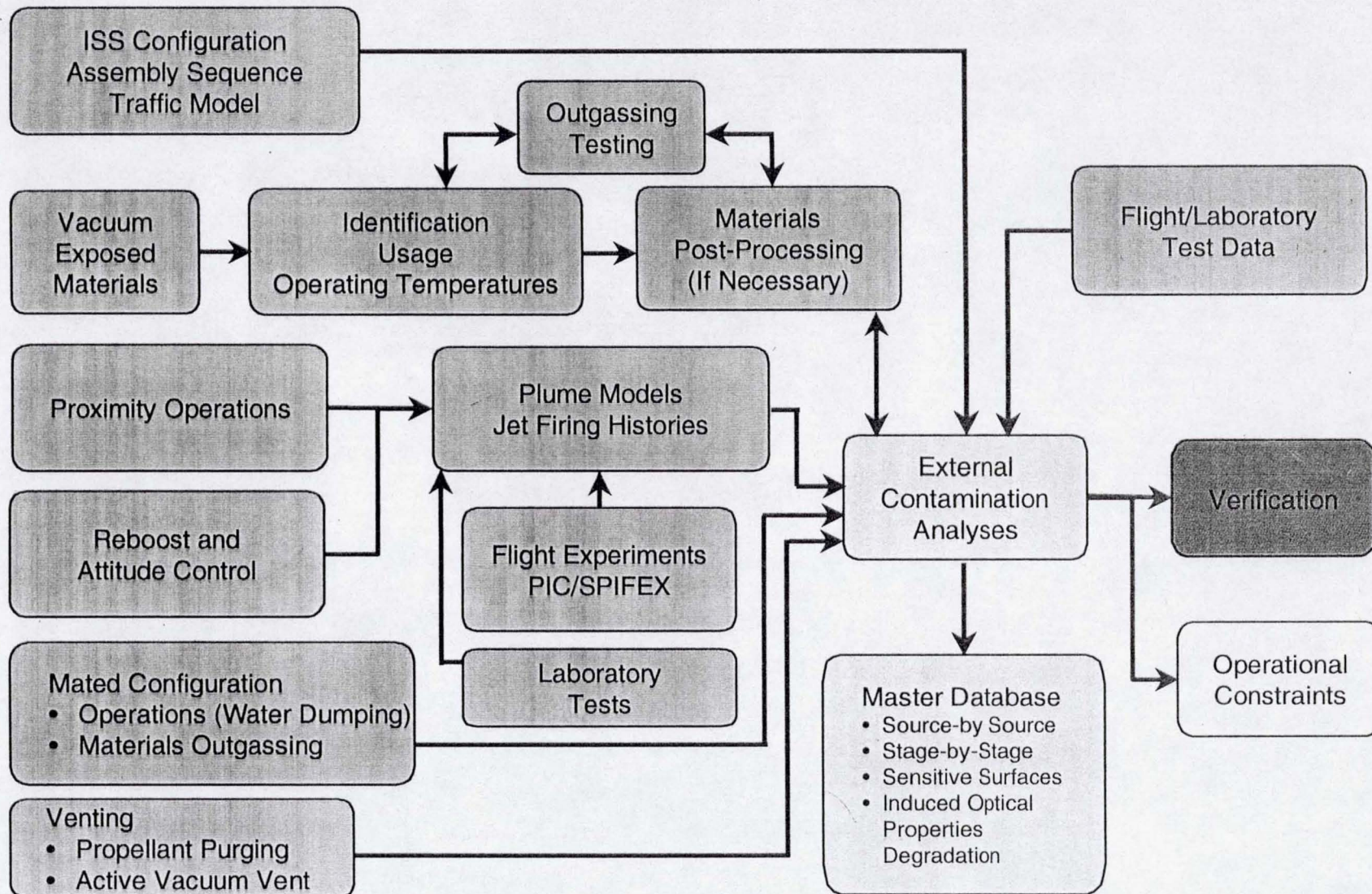
- **Analyses for Verification**
- **Laboratory testing**
 - ▢ **Materials outgassing**
 - ▢ **Water venting**
 - ▢ **Optical degradation due to induced external contamination and environmental exposure**
 - ▢ **Plume measurements**
- **Flight Experiments and observations**
 - ▢ **Space Shuttle flight experiments**
 - ▢ **Mir flight experiments**
 - ▢ **Shuttle-Mir (Phase 1) Risk Mitigation Experiments**

On-Orbit

- **Inspection of hardware**
- **Flight imaging (flight-by-flight)**
- **ISS flight data:**
 - ▢ **Vehicle performance**
 - ▢ **Payloads environmental data**



ISS External Contamination Control for Pre-launch Verification





Flight Experiments and Observations



● Mir

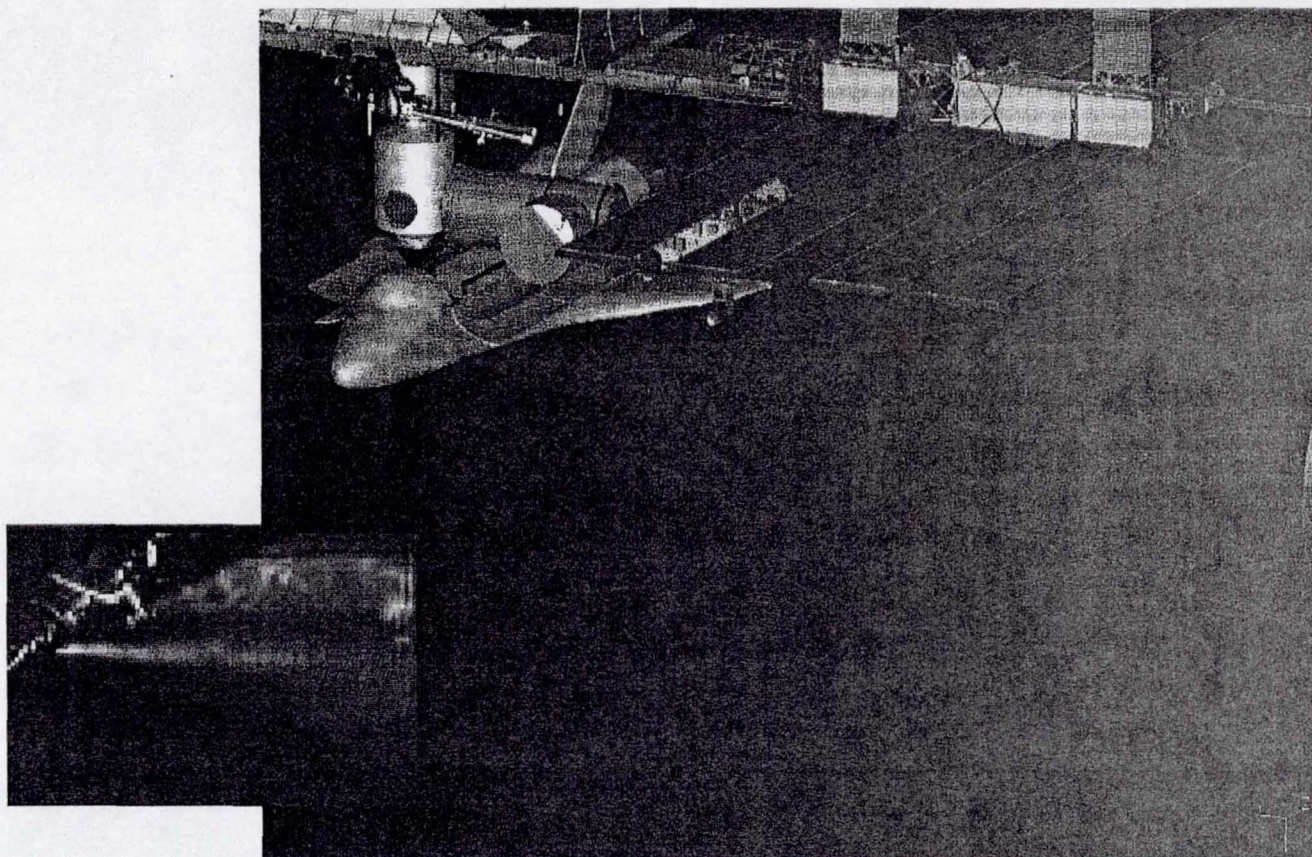
- Docking Collar Camera Bracket (U.S.)
- ICA (ESA Euro-Mir '95)
- Astra-II (Russian)
- Comes-Aragatz (French)
- Mir Imaging (U.S.)
- TREK (U.S.)
- Phase 1 Risk Mitigation Experiments (U.S.):
 - Mir Environmental Effects Payload (MEEP)
 - Optical Properties Monitor (OPM)
 - Space Portable SpectroReflectrometer (SPSR)
 - Mir Solar Array Return Experiment (SARE)

● Space Shuttle

- SPIFEX (STS-64)
- PIC (STS-74)
- Water Dump (STS-29)
- IECM (STS-2, STS-3, STS-4)
- IOCM (STS-34, STS-44)
- HST SM2 (STS-82)
- EOIM-III (STS-46)
- AMS (STS-91)
- Long Duration Exposure Facility (LDEF)
- Hubble Space Telescope (HST)



Example Flight Observation: Space Shuttle Orbiter Waste Water Dump





Materials Outgassing

- All materials which are possible sources of contamination undergo outgassing rate testing.
- Condensable materials outgassing rates are obtained by long duration ASTM E 1559 testing.
 - Material sample (emitter) is tested over the on-orbit operational temperature range identified by the ISS system level thermal model.
 - Temperature-Controlled Quartz Crystal Microbalances (TQCMs), or receivers, are held at different temperatures covering the typical range of operational temperatures of ISS contamination sensitive hardware, such as the Active Thermal Control System (ATCS) and passive radiators.
 - Testing is of long duration, typically 144 hours.
- ASTM E 595 testing is used as an initial screen.



Active Vacuum Vents

- The current ISS vent database identifies 33 active vacuum vents on the International Space Station.
- Vacuum venting must comply with molecular column density and molecular deposition requirements.
 - ISS vents are considered quiescent sources (with exception of the U.S. Lab condensate water vent which is considered non-quiescent until assembly complete).
 - Most ISS vents do not produce molecular deposits on ISS surfaces. Typical exhaust composition for these vents include air, carbon dioxide and hydrogen.
 - Molecular column density (MCD) requirements limit mass flow rates for ISS vents. Scheduling of venting events may be required for vacuum exhaust systems on U.S. Lab, ESA Columbus module and JEM Pressurized Module due to their high flow rate capacities to accommodate internal payloads.

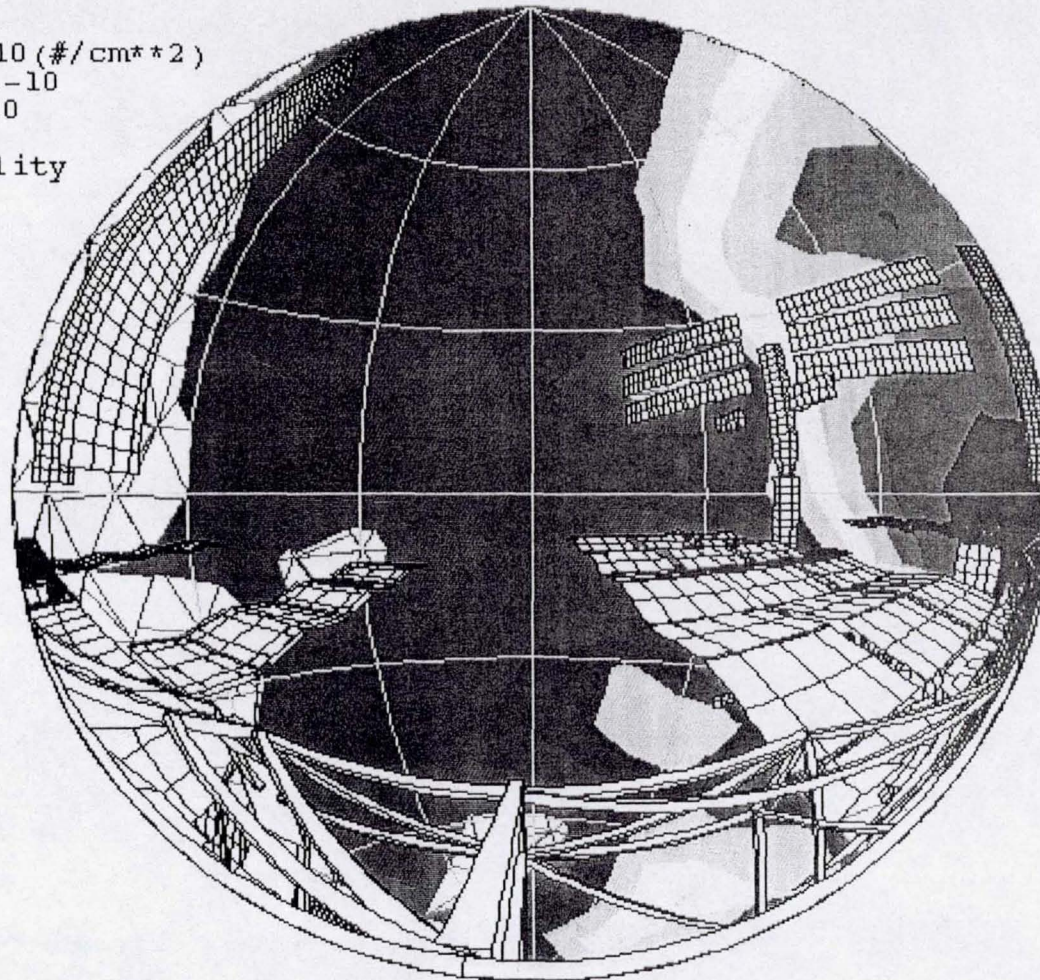
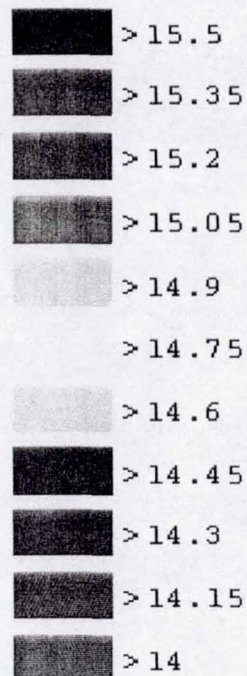


Example of Molecular Column Density Profile



View from Starboard Upper Payload Position Looking in the Wake Direction

BUW View - $\log_{10}(\#/cm^2)$
Location : 0,75,-10
Direction : -1,0,0
LAB1 VES "T"
Combustion Facility



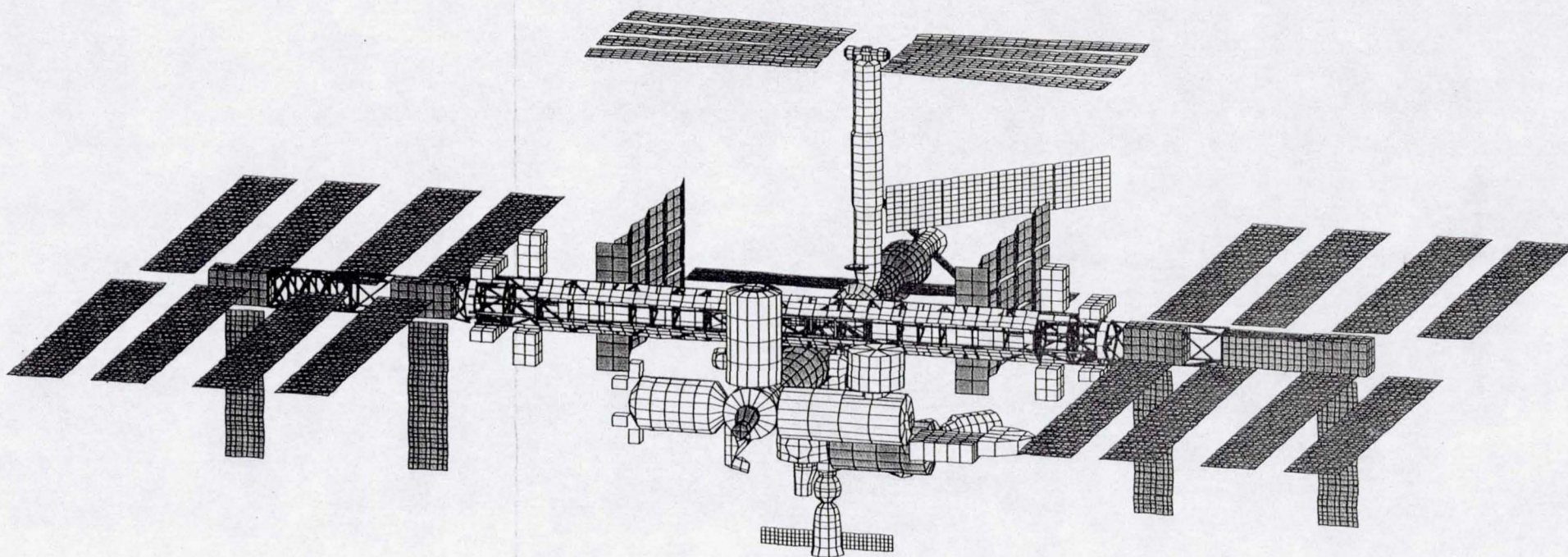


Modeling and Analysis Tools

- The NASAN program is used to model external contamination for the ISS program.
 - Evolved from the MOLFLUX program, previously used during the Space Station Freedom program.
 - NASAN can model up to 100,000 surface elements, with variable geometry and multi-spacecraft interactions. MOLFLUX was limited to about 3,000 to 4,000 surfaces, with fixed geometry.
 - NASAN produces output in graphical format, condensing hundreds of pages of information in a single color plot.
- Direct Simulation Monte Carlo (DSMC) methods have been employed to model return flux and small features of specific problems encountered during ISS design activities.
- A Smooth Particle Hydrodynamics (SPH) code is being used to examine particle impacts to ensure no damage to ISS structures.



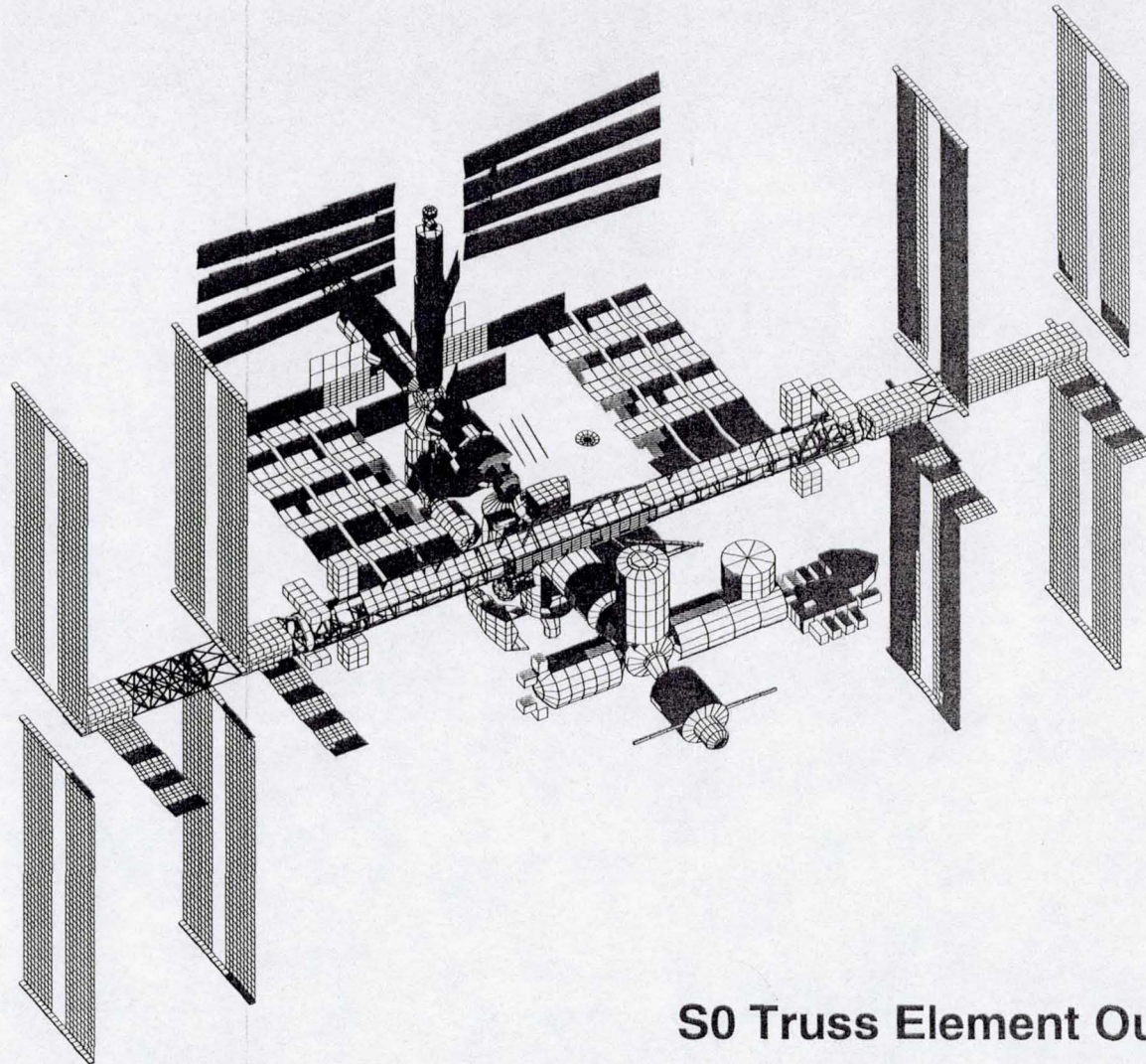
Sources of Outgassing Induced Contamination Analyzed To Date



Note: Elements analyzed
shown in color.



Example of Outgassing Induced Contamination Analysis



S0 Truss Element Outgassing

ISS External Contamination: Quiescent Sources

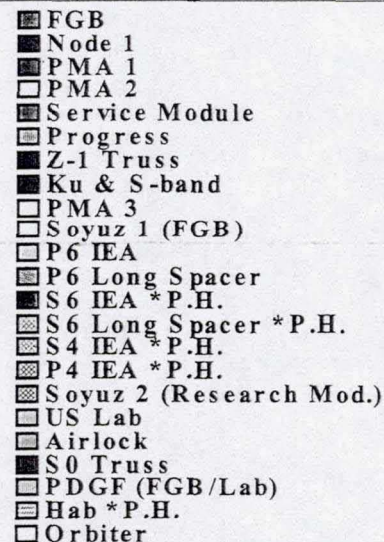
Sources: FGB, Node 1, PMA1, PMA2, Service Module, Progress, Z-1 Truss, Ku & S-band Antennas, PMA3, Soyuz 1, P6 IEA, P6 Long Spacer, S6 IEA (PH), S6 Long Spacer (PH), S4 IEA (PH), P4 IEA (PH), Soyuz 2, US Lab, Airlock, S0, Hab (PH), PDGF, Orbiter

Assembly Complete Total Yearly Deposition (Å/year)

0 5 10 15 20 25 30 35 40

ISS Vehicle - Sensitive Surfaces

PMA1 MDM RAD (-Z) ST TOP (+Y)
PMA1 MDM RAD (-Z) PT TOP (-Y)
PMA1 MDM RAD (+Z) STLWR (+Y)
PMA1 MDM RAD (+Z) PTLWR (-Y)
RSA SMPV ARRAYS ST FRONT (-Z)
RSA SMPV ARRAYS PT FRONT (-Z)
RSA SMPV ARRAYS ST BACK (+Z)
RSA SMPV ARRAYS PT BACK (+Z)
P6 PV ARRAYS PANEL A FRONT (-Z)
P6 PV ARRAYS PANEL B FRONT (-Z)
P6 PV ARRAYS PANEL A BACK (+Z)
P6 PV ARRAYS PANEL B BACK (+Z)
EA/AC RADIATORS P6 ST/FRONT (+Y)
EA/AC RADIATORS P6 PT/BACK (-Y)
EA/AC RADIATORS S4 FRONT (+X)
EA/AC RADIATORS S4 BACK (-X)
EA/AC RADIATORS S6 PT/FRONT (-Y)
EA/AC RADIATORS S6 ST/BACK (+Y)
LAB WINDOW NADIR SIDE (+Z)
S0 THERMAL RAD S0 TRUSS BACK (-X)
RSA MAST ARRAYS ST FRONT (-Z)
RSA MAST ARRAYS PT FRONT (-Z)
RSA MAST ARRAYS ST BACK (+Z)
RSA MAST ARRAYS PT BACK (+Z)
MASTRADIATORS FRONT (+X)
MASTRADIATORS BACK (-X)
P3/P4 PV ARRAYS PANEL A FRONT (-Z)
P3/P4 PV ARRAYS PANEL B FRONT (-Z)
P3/P4 PV ARRAYS PANEL A BACK (+Z)
P3/P4 PV ARRAYS PANEL B BACK (+Z)
P4 TCS PV RADIATOR P4 FRONT (+X)
P4 TCS PV RADIATOR P4 BACK (-X)
ATCS RADIATORS ST PANEL A (+Y)
ATCS RADIATORS PT PANEL A (+Y)
ATCS RADIATORS ST PANEL B (-Y)
ATCS RADIATORS PT PANEL B (-Y)
S3/S4 PV ARRAYS PANEL A FRONT (-Z)
S3/S4 PV ARRAYS PANEL B FRONT (-Z)
S3/S4 PV ARRAYS PANEL A BACK (+Z)
S3/S4 PV ARRAYS PANEL B BACK (+Z)
CUPOLA WINDOWS PT SIDE (-Y)
S6 PV ARRAYS PANEL A FRONT (-Z)
S6 PV ARRAYS PANEL B FRONT (-Z)
S6 PV ARRAYS PANEL A BACK (+Z)
S6 PV ARRAYS PANEL B BACK (+Z)



Prepared by:

Approved by:

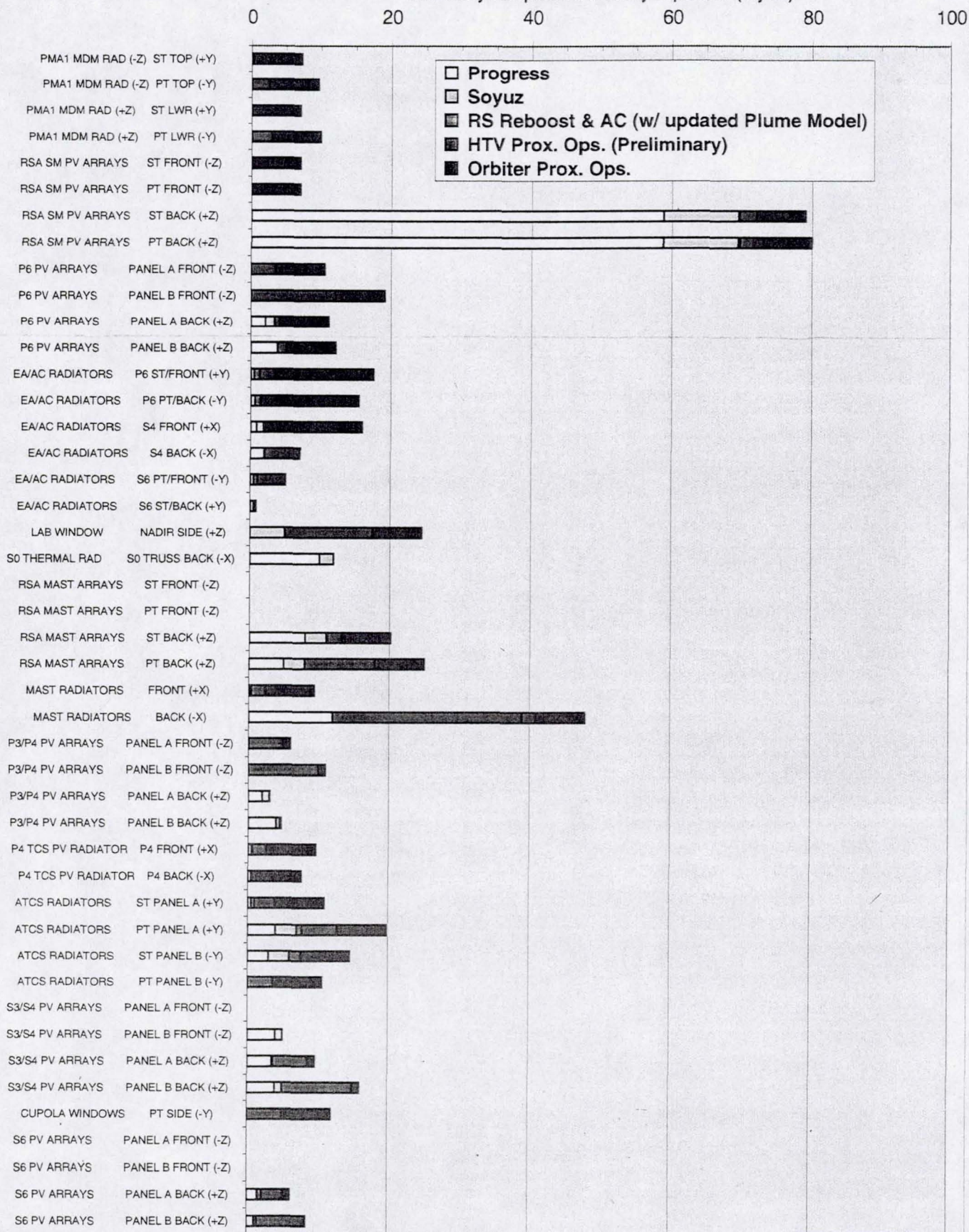
Original Signed by _____
Carlos Soares and John Alfred

Original Signed by _____
Ron Mikatarian

ISS External Contamination : Non-Quiescent Sources

Sources : Progress, Soyuz, Russian Segment Reboost & Attitude Control, HTV, Orbiter
Assembly Complete Total Yearly Deposition (Å/year)

ISS Vehicle - Sensitive Surfaces





Observations on Optical Degradation **BOEING®** due to Induced External Contamination in LEO

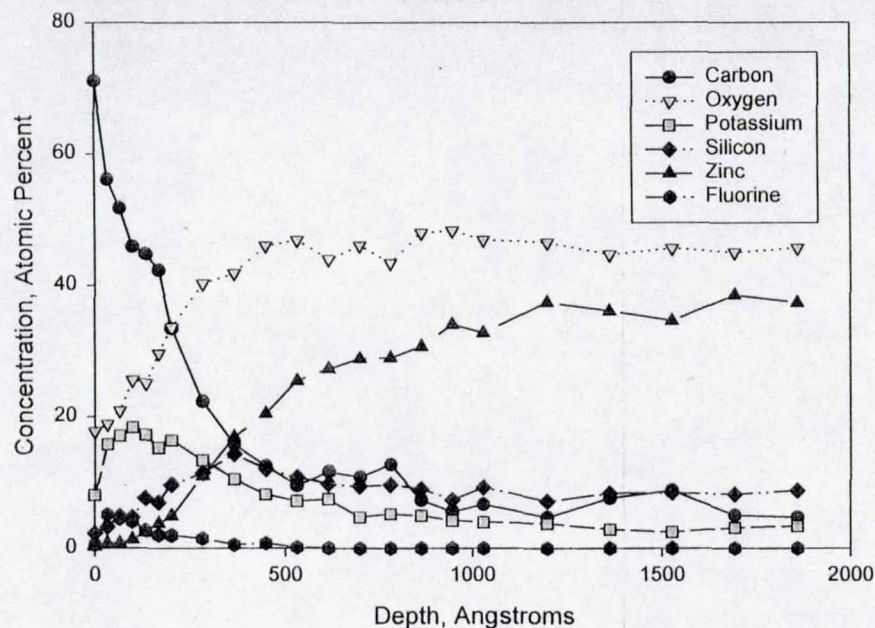
- Organic silicones typically convert to silicates (SiO_x) on-orbit due to AO/VUV exposure.
- Hydrocarbon contaminants usually erode on-orbit due to AO exposure.
- On orbit, silicone contaminants deposit on surface. In the laboratory, silicone and hydrocarbon contaminants diffuse into the porous structure of the substrates.
- Optical degradation on samples pre-contaminated with hydrocarbons observed to recover on-orbit.
- On-orbit induced contamination optical degradation depends on contaminant flux, AO flux, and VUV exposure.



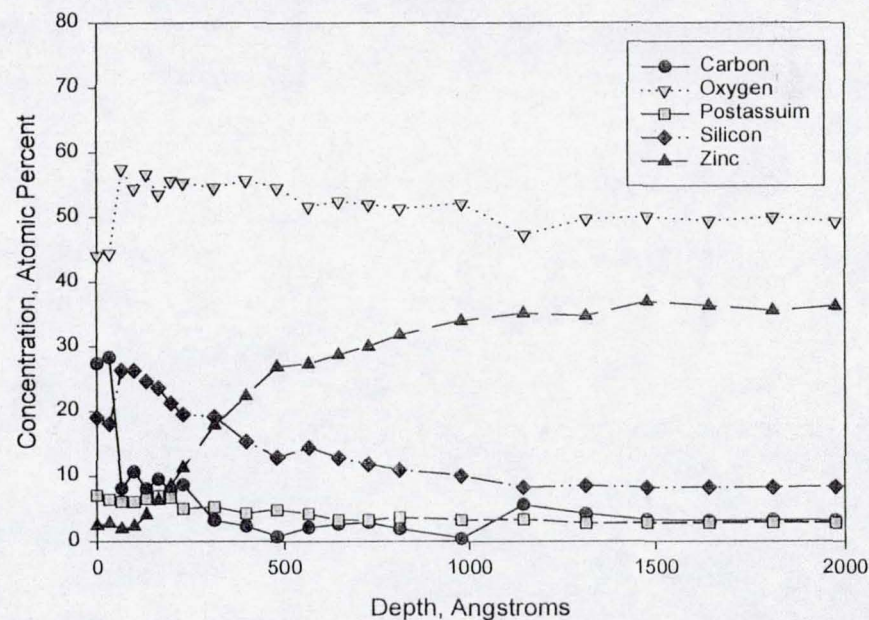
Example of Typical Contaminant Profile



Sample AZC027: Pre-contaminated Z93 White Ceramic Paint - Ground Control



Sample AZC028: Pre-contaminated Z93 White Ceramic Paint - Flight Exposed

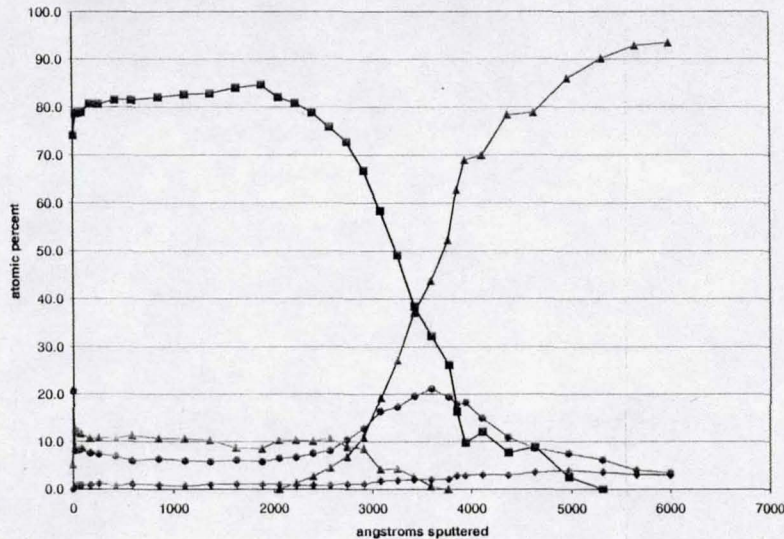




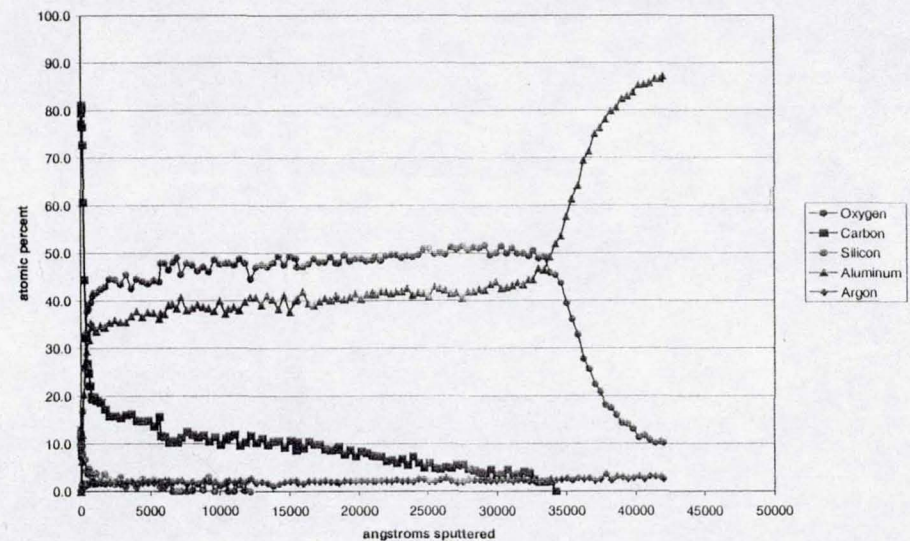
Examples of Contaminant Depth Profile



Clad Aluminum Substrate



Sulfuric Acid Anodized Aluminum Substrate





STATUS



ISS System

- System Level Requirements will be met.

Material Outgassing

- Process in place working effectively with US and IP hardware producers to control external contamination.

Thruster Plumes

- New activity in place for developing updated plume contamination model.
 - ▢ Laboratory tests being conducted.
 - ▢ Space Shuttle flight test in 2001 (STS-108).

Optical Degradation

- Activity in place for developing updated LEO external contamination optical degradation model.
- Laboratory tests being conducted.